crystals, especially of type WBB, cease to grow and are succeeded by type WFC. In many cases the latter type adopts the former as a nucleus and grows outward therefrom.

We have selected 18 examples of this most elegant type of window-frost crystal for use as illustrations, as follows: Nos. 30, 31, 42, 69, 73, 115, 117, 130, 131, 132, 146, 147, 148, 177, 179, 195, 196 A, 196 B. Nos. 130, 131, and 196 A are particularly lovely and interesting examples. As will be noted, some of them resemble sea moss. Tiny crystals of type WBB form the nuclei of specimens Nos. 130, 131, 132, and 195.

Sometimes a very slight change (increase) in the indoor humidity, accompanied by a fall of but a few degrees in outdoor temperature, will cause crystals of this type to form and grow between or around crystals of type WBB, as shown in the very interesting photograph No. 196 B.

*(34) Type WMD. Meandering window frost.*

These singular frost crystals consist in some cases of but a single straight or curving spike or quill, and in others of a central quill adorned with a few or with many secondary tuft-like branches. Such tuft-like secondary branches as may form upon and around the primary quill or spike usually appear clustered together into tufts thereon. Singularly enough many of the secondary branches grow outward from the central quill perpendicularly rather than at an angle of 60°.

These odd crystals are essentially very cold weather types and form only within cold, unheated rooms during below-zero weather. They form freely only when the indoor temperatures range from 15° F. downward. They form freely in a very cold atmosphere, when the relative humidity of the air ranges from 77 to 86 per cent, and less freely within warmer air at humidities of from 55 to 65 per cent. Sometimes the longer varieties of this type of crystal seem to possess a structure nearly continuous, as in Nos. 175, 176, and 178, while in other cases they seem to be built outwardly in sections, as in Nos. 58 A, 58 B, 59, 154 A, 154 B, and 188.

*(35) Type WSE. Stelliform crystals.*

Crystals of this type are of a somewhat close structure. In many cases a simple hexagonal star forms the nucleus, the rays of which terminate in tiny solid hexagonal plates.

They commonly form around and upon tiny bits of ice, or tiny frost crystals, and usually develop parallel to, but slightly raised from, the window glass, except when their nucleus is itself attached to the glass. They evidently grow outward in intermittent, rather than continuous, order, whenever the temperature suddenly falls, or a windowpane is suddenly cooled far below its previous temperature, as the result of a cold gust of wind suddenly springing up and striking it. They are slow-growing, cold weather types, and occur only in cold rooms and during below-zero weather. Indoor temperatures must be as low as 20° F. for them to form freely. They form most freely within cold rooms at humidities ranging from 74 to 90 per cent, less freely at milder temperatures, when the relative humidity ranges from 55 to 65 per cent.

They usually fail to attain perfectly symmetrical proportions, for the reason that they commonly form in such a position that their growth does not progress equally in all directions. In rare instances their position and environment is such as to allow development to proceed in all directions, and in such cases they assume quite symmetrical forms. See Nos. 161 and 154 B (it is to be noted that one point of No. 161 is broken partly off).

Crystals of this same general character sometimes form around, or develop annex-fashion from, other frost types. No. 145 A is a very beautiful and unique example, in which the stelliform crystal formed around and grew outward as an annex to the branching type of window frost, type WBB.

It is to be noted that this type of frost, altho for convenience grouped under the title "Window frost", develops largely outward from, and independent of, the surface of the glass, and hence is in reality a type of indoor hoarfrost. (See type HTF, tabular hoarfrost, section 16.)

[*To be continued.*]

## INTERNATIONAL METEOROLOGY.

The following is an extract from an address by Prof. Arthur Schuster, of Manchester, delivered before the Royal Institution of Great Britain Friday, May 18, 1906, and is reprinted from Nature and from the Annual Report of the Smithsonian Institution for 1906:

In an address delivered to the British Association at its Belfast meeting, in 1902, I expressed the opinion that meteorology might be advanced more rapidly if all routine observations were stopped for a period of five years, the energy of observers being concentrated on the discussion of the results already obtained. I am glad to say that meteorologists have taken seriously a remark the echoes of which still reach me from distant parts of the earth. They disagree with me, but their disagreement is of the apologetic kind. I do not wish to retract or to weaken my previous statement, but merely now qualify it to the extent that it is only to be applied to two-dimensional meteorology. There is a three-dimensional meteorology as far removed from the one that confines itself to the surface of the earth as three-dimensional space is from a flat area. Three-dimensional meteorology is a new science, which at present requires the establishment of new facts before their discussion can properly begin. The extension of our range of observations by kites and balloons is of comparatively recent origin. Mr. Archibald in this country was one of the pioneers of meteorological investigation by means of instruments attached to kites. In the United States Mr. Rotch, having established a separate observatory, succeeded in convincing scientific men of the great value of the results which could be obtained. Mr. L. Teisserenc de Bort, who established and maintained an observatory for dynamic meteorology at Trappes, near Paris, rendered similar services with regard to "pilot" or unmanned balloons carrying autographical instruments. The aeronautical department of the Royal Prussian Meteorological Institute, with Doctor Assmann at its head, under the direction of Professor von Bezold, also made a number of important contributions in the early stages of the work. Professor Hergesell, of Strasburg, similarly made numerous experiments; and chiefly through the efforts of those whose names have been mentioned, and more especially Professor Hergesell, an international agreement has been secured by means of which kite and balloon ascents are made in several countries on the first Thursday in each month and on three consecutive days during two months of the year. A large station for aeronautical work was recently established at Lindenburg, near Berlin, where kites or balloons are sent up daily for the purpose of securing meteorological records. The greatest height yet reached was during the ascent of the 25th of November, 1905, when by means of several kites sent one after another on the same wire the upper one rose to an altitude of 6430 meters, almost exactly four miles. Owing to want of funds this country could until recently only participate in this work through the individual efforts of Mr. Dines, who received, however, some assistance from the British Association and the Royal Meteorological Society.

The reconstruction of the meteorological office has made it possible now for Mr. Dines's work to be continued as part of the regular work of that office, and further stations are being established. Mr. Cave carries out regular ascents at his own expense at Ditcham Park, and through the cooperation of the

Royal Meteorological Society and the University of Manchester, assisted by a contribution for apparatus from the Royal Society government grant fund, a regular kite station is being established on the Derbyshire moors.

The international committee which collates the observations is a commission appointed by a union voluntarily formed between the directors of meteorological observatories and institutes of countries in which regular observations are taken. The meeting of directors discusses schemes of observations and encourages uniformity.

If I mention a few of the difficulties which stand in the way of a homogeneous system extending over Europe, I do so in the hope that it may perhaps ultimately assist in removing some of them. It is obviously desirable that the charts, which are intended to show the distribution of pressure and temperature, should be derived from observations made at the same hour. Germany observes at 8 o'clock of Central European time, and France observes simultaneously (or nearly so) by choosing 7 o'clock, Paris time, for its readings. We observe at 8 o'clock, Greenwich time, which is an hour later. It is the great desire of continental meteorologists that our standard hour should be 7 o'clock, and what prevents it from being so? Chiefly and absolutely the additional cost which the post-office must claim for the transmission of telegrams; because messages transmitted before 8 o'clock are subject to an additional charge of one shilling, which may be claimed by the postmaster, the claim being possibly increased to two shillings when the postmaster and telegraphist are different persons. This is prohibitive, but it does not exhaust the inconvenience of the additional charge. For the purpose of weather forecasting it is clearly necessary that telegrams should be received as early as possible by the meteorological office. But the 8 o'clock rule delays telegrams from some Irish stations, because 8 o'clock by Dublin time is 8:25 by Greenwich time, and therefore Irish telegrams may have to wait until nearly half past 8 if they are to be transmitted without extra charge.

While the international organization of meteorology is well on its way, though difficulties such as those I have mentioned may temporarily retard it, another question not altogether disconnected with it has been raised by Sir John Eliot. This is the establishment of an institution devoted to the collective study of meteorological problems affecting all parts of the British Dominions. It is true, not only in this but also in other matters, that in order to take our proper position in international work it is necessary that we should set our own house in order, and we must give Sir John Eliot's proposals our hearty support. If I do not enter further into this question, it is because I am now dealing more especially with problems which go beyond the limits of the Empire. I assume the existence of a national organization, but lay stress on the insufficiency of this limitation.

The importance of the subject, however, may be my justification, if I direct attention for a moment to the meteorological question as it presents itself in India. We all know and realize the vital importance of the rainy season, and the benefit which the native population would derive if it were possible to predict, even if only imperfectly, the setting in of the monsoon. It appears that Doctor Walker, the present director of observatories in India, recently obtained very encouraging results in this respect. According to his investigations, a forecast of the monsoon may be derived from a knowledge of the weather during preceding months in different parts of the world. Thus a heavy rainfall in Zanzibar in May is followed by a weak monsoon, while a pressure deficiency in Siberia during the month of March indicates a probable deficiency of rain in India during the following August. I need not insist on the importance of these results, which at present are purely empirical and require further confirmation, but it is quite clear that for the successful prosecution of these inquiries political boundaries must be disregarded and a system of intercommunication organized between the countries chiefly concerned. Doctor Walker informs me that he has successfully arranged for telegraphic reports to be sent to him at the beginning of June from six different stations in Siberia. It is hoped that this cooperation, which was unavoidably discontinued during the late war, may now be reestablished.

The course of international organizations does not always run smoothly. The efforts made toward cooperation in earthquake records have unfortunately led to differences of opinion, which have hitherto prevented a truly international system being formed; and if I give a short historical account of the circumstances which have led up to these differences, it is only in the hope that this may help to remove them. The scientific investigation of earthquakes may be said to have begun when British professors of physics, engineering, and geology were appointed at the Imperial College of Engineering in Tokyo. Some of them on returning home succeeded in interesting the British Association in the subject. Ever since 1880 that association has been an active supporter of seismic investigations. The much disturbed region of the Japanese islands was naturally the first to be studied, but in 1895 Professor Milne, as one of the secretaries of the committee, issued a circular calling attention to the desirability of observing waves which have traveled great distances, and some months later Dr. E. v. Rebeur-Paschwitz, of Strasburg, drew up suggestions for the establishment of an international system of earthquake stations. To this scheme Professor Milne and other members of the British Association committee gave their approval. The cooperation which thus seemed so happily inaugurated was broken by the unfortunate death of its originator. Circumstances then arose which compelled the British Association committee to go its own way. Under its direction a system was established which now includes about forty stations distributed all over the world. But the needs of different countries are not, and were not, meant to be satisfied by this organization.

There is always a certain number of earthquakes having purely local importance and requiring discussion from a purely local point of view. For the purpose of such discussion relating to the disturbances which chiefly affect central Europe, the union, so-called "kartell", of the academies of Vienna, Munich, Leipzig, and Göttingen formed a committee and did excellent work. In the meantime Professor Gerland, who had succeeded Doctor Rebeur-Paschwitz at Strasburg, had personally invited a number of friends interested in the subject to a conference at Strasburg, with the object of forming an international association. This was followed in 1903 by a formal conference called by the German Government, at which Great Britain was represented by Sir George Darwin and Professor Milne. This conference drew up a scheme for an international association, and a large number of countries, including Russia and Japan, joined. Strasburg was selected as the seat of the central bureau. The matter came up for discussion at the meeting of the International Association of Academies, which was held in London in 1904, and a committee was appointed for the purpose of suggesting such modifications in the constitution of the seismic organization as might bring it into harmony with the views of the associated academies. This committee, over which I had the honor to preside, met at Frankfort and recommended a number of important changes, which were unanimously accepted by the second seismic conference, held last summer in Berlin. In consequence of this acceptance, it appears that Italy and the United States joined the seismic association, while England declared its willingness to join under certain conditions, of which the simultaneous adhesion of France was one. The following summary of the States which have joined and their population is copied from the official report of the last meeting at Berlin:

| Country. | Population. | Contribution. | Country. | Population. | Contribution. |
|---|---|---|---|---|---|
| German Empire.... | 60,000,000 | £160 | Italy.............. | 33,000,000 | £160 |
| Belgium............ | 7,000,000 | 40 | Mexico ........... | 13,600,000 | 80 |
| Bulgaria........... | 3,700,000 | 20 | Norway............ | 2,300,000 | 20 |
| Chile............... | 3,000,000 | 20 | The colonies of the Netherlands .... | 5,500,000 | 40 |
| Kongo State........ | 19,000,000 | 80 | Portugal........... | 5,400,000 | 40 |
| Spain............... | 19,000,000 | 80 | Roumania......... | 6,300,000 | 40 |
| United States....... | 76,000,000 | 160 | Russia............ | 129,000,000 | 160 |
| Greece ............ | 2,500,000 | 20 | Switzerland........ | 3,300,000 | 20 |
| Hungary............ | 19,250,000 | 80 | | | |
| Japan .............. | 48,000,000 | 160 | | | |

It was decided at the Berlin meeting that Professor Kövesligethy, of Budapest, should be secretary and Professor Palazzo, of Rome, the vice-president of the International Seismic Association. Professor Gerland had already previously been designated as director of the central bureau. The office of president of the association was left vacant until the final decision of Great Britain as to its adhesion had been settled. There the matter stands for the present.

The disastrous results of recent earthquakes and volcanic eruptions have directed increased attention to the subject. Its thorough investigation is indeed likely to yield important information on the interior constitution of the earth. A hearty cooperation to obtain and circulate the material for a detailed discussion can not fail to bear fruit, and even though there may be legitimate grounds for dissatisfaction at the manner in which a particular scheme has been organized, I must express my own opinion that at the present moment the permanent interests of this country would be best secured by our joining the association and helping to direct its work in a manner which would assist rather than hamper the present organization of the British Association.

## THE SPECTRUM OF THE AURORA BOREALIS.

By Dr. W. MARSHALL WATTS. Dated Sydenham, England, September 14, 1907.

Among the rare and striking phenomena of nature, the aurora borealis, or "northern lights", has always excited much interest. The earlier explorers of the Arctic regions made frequent observations of it, and speak of it in glowing terms, describing it as either a long tranquil arc of silver light, stretching along the northern horizon, with its highest point in or near to the magnetic meridian; or as broken cloud-like masses of a glowing ruddy light, with streamers and golden rays, compared to aerial spears, shooting from the arc and sometimes reaching to the zenith, forming an appearance resembling a crown—the "corona borealis".

Upon the invention of the spectroscope scientific observers were eager to apply the new method of investigation to the aurora. Among the earliest observers of the spectrum was Ångström, who, in the winter of 1867–68, observed[1] on several occasions the spectrum of the luminous arc bordering the dark segment, which is always to be seen in the aurora even when faint. Its light proved to be almost monochromatic, and consisted of a single brilliant greenish line to the left of a group of known lines of calcium.

Measuring the distance of the auroral line from this group, Ångström determined its wave length to be 5567.[2] Besides this line, of which the intensity is relatively great, Ångström observed also, by widening the slit, traces of three faint bands extending nearly to *F*. Ångström remarks that this chief auroral line does not coincide with any known line in the spectra of simple or compound gases. Otto Struve, of Pulkowa, to whom Ångström communicated his result, also made measurements, which gave for the position of the line 1259 of Kirchhoff's scale, or wave length 5552.

[1] Ångström: "Recherches sur le Spectre Solaire".

[2] That is, 5567 "Ångström units" or hundred-millionths of a centimeter, or 5567 ten-millionths of a millimeter, or 556.7 micro-millimeters or 556.7 $\mu\mu$, or 0.5567 microns, or 0.5567 $\mu$.—EDITOR.



In a paper of later date[3], Ångström discusses the probable origin of the auroral line, and gives it as his opinion that the spectrum consists of two portions, the chief line being due to phosphorescence (or fluorescence) and the other lines to rarified air, the conditions of temperature and pressure, so different in the upper regions of the atmosphere from those in the laboratory, sufficing to explain all divergencies. He says:

> The one spectrum results from the monochromatic yellow light which is always seen even in the feeblest traces of the aurora, and which, on clear winter nights, is perceived from all parts of the sky. The other spectrum consists of extremely feeble lines or bands, and it is only in the strongest auroras that it is possible to measure their position even approximately. Piazzi Smyth[4] observes that the chief line of the aurora falls between the second and third lines of the greenish yellow hydrocarbon group; and Vogel[5] remarks that it is coincident with a line in the spectrum of rarified air. This latter observation is correct, but in my opinion this is the result of the purest accident. The red lines—first observed by Zöllner—seldom occur. There is no doubt that the spectrum varies at different times. The discharge is sometimes disruptive, and sometimes by conduction; it occurs sometimes in the extreme limits of the atmosphere, and sometimes at short distances from the earth's surface.

Ångström observed (on April 18, 1873) lines at 5567, 521–, 501–, 487–, 472–. He quotes the observations (of presumably the same lines) by Barker[6] as 431–, 4705, by Vogel[7] as 4694, 5233, and Lemström[8] (November 19 and 22, 1872) as 5568, 5235, 4694, 4262, and thinks that the means of these measurements agree fairly well with the lines 5227, 4707 and 4272 observed in the violet light at the negative pole in rarified air.

Vogel[9] observed the auroral spectrum on several occasions in 1870 and 1871. The instrument he used was the star spectroscope belonging to the 11-inch equatorial of the Bothkamp Observatory, consisting of a set of direct vision prisms, with slit, collimator, and observing telescope with a magnifying power of four. The measuring apparatus consisted of a micrometer screw, the head of which was divided into 100 parts. This moved a fine steel point in the field of view, and the point could be illuminated by a small lamp if required. The readings of the micrometer were reduced to wave lengths by means of readings of about 100 Fraunhofer lines found in Ångström's Normal Map of the Solar Spectrum. After each observation of the auroral spectrum readings of the sodium line or of the hydrogen lines were taken by way of control.

A very bright aurora was observed on October 25, 1870. The spectrum showed the green line and several fainter lines toward the blue on a dimly lighted background, extending over *E* and *b*, and half-way from *b* to *F*. No measurements were taken on this occasion.

On February 11, 1871, an aurora was seen; the average of six readings of the brightest line was 5573. No lines in the red were seen. On February 12 an average of six readings gave 5572; Doctor Lohse also took six readings and obtained 5569. The appearance of the spectrum on this occasion was essentially different from that of February 11. The green continuous spectrum was present from 5572 to *b* and traversed by some bright lines between *b* and *F*, one line beyond *F*, and just before *G* a faint broad band. Later a red line between *C* and *D*, but nearer *C* than *D*, made its appearance.

On April 9, 1871, a very bright aurora was seen, showing a red sheath rising nearly to the zenith. The spectrum was similar to that of February 12, but much more intense, showing five lines in the green, and a broad band in the blue. The red ray allowed him to recognize seven lines, for which the

[3] Ångström, Pogg. Ann., Jubelband, p. 424.

[4] Piazzi Smyth, C. R. [Comptes Rendus], LXXIV, p. 597.

[5] Vogel, Pogg. Ann., CXLVI, p. 582.

[6] Barker, American Journal of Science, (3), II, 465; V, 81.

[7] Vogel, Pogg. Ann., CXLVI, p. 573.

[8] Lemström, Polarljuset och Polarljusspektrum. Helsingfors, 1873.

[9] Vogel, Pogg. Ann., CXLVI.